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November 10, 1964

Winnie M. Morgan, M. D.
Report Control Officer
Grants and Research Contracts
Office of Space Science
National Aeronautics and Space Administration
Washington 25, D. C.

Re: Voucher No. 12 for Contract NASr-83

Dear Dr. Morgan:

The following is our progress report for the period July 1 through September 30, 1964.

Monkey Project:

Thirteen orbits were run this quarter bringing the total number of orbits completed on the project to 160. The orbits were distributed over the three senior Nemestrina monkeys as follows: NA-5, 5 orbits; NA-6, 4 orbits; and NA-3, 4 orbits.

This quarter, modifications were made in the reward contingencies and in the timing of the problems used in orbit. The red light problem, which was used last quarter with a pellet reward every trial, was used this quarter without any pellet rewards in 4 orbits and then with a pellet for every fourth response in 5 orbits. Output was better with pellets for every fourth response than with either no pellets or pellets every trial. (See figure 1). The effectiveness of this reinforcement schedule with the red light problem suggests that there would be little risk in extending it to the reversal and interpolated cue problems if a tone sounded after each correct response to tell the animal he had chosen correctly. This will be done next quarter so that even without the red light problem the number of pellets available with perfect accuracy can be brought below the quantity the animals consume in 48 hours of ad libitum feeding. The red light problem is less desirable because its only parameter is output.

The timing of the orbit problems was modified to require greater vigilance. Regular inter-trial intervals were replaced by four different intervals in random sequence, and problem durations were minimized so that the animal had to respond immediately whenever a problem appeared. Monitoring has been more apparent with these changes and they have coincided with the first accuracy decrements in two of the animals. (See figure 2.) The output of these animals also decreased over time in about the same degree as in orbits before the vigilance requirement. (See figure 3). Thus, the occurrence of accuracy decrements cannot in these instances be related to maintenance of output.

Accuracy decrements were obtained from NA-5 on both problems of orbit 157 (figure 4), but his output fell off more than accuracy in orbits 152 and 160.

Late in the quarter NA-6 died. The autopsy showed gastritis, enteritis, colitis, and a chronic pneumonia. All of the other animals have remained in good health. Four new monkeys have arrived (NA-16, NA-17, NA-18, and NA-19) and joined NA-15 in training on discrimination problems. NA-16 has mastered the discriminations and will soon start on reversals. Of our middle group of monkeys, NA-12 now reverses his choices on a color problem every few days, and NA-10 and NA-11 have mastered reversals every 50 trials in 200-trial sessions. They will soon start matching problems, and it is hoped to orbit them for the first time late next quarter.

Training procedures have been modified in that the animals now sit before the panel in a modified carrying case. They are not chaired anymore except when ready access to a particular animal is requested by the veterinarian. The animals seem much healthier and perform much better without the spectre of chairing. EEG electrodes (skull screws) will be placed in NA-15, NA-16, NA-17, NA-18, and NA-19 when the animals are ready for their first orbit.

Chimpanzee Project:

The chimpanzees have been kept on a discrimination problem designed for transfer directly to the tick-tac-toe task which is nearly ready for them. Their behavior during testing has greatly improved since reinforcements earned while working at the panel have become the only food available to them. Preliminary investigation has been made of the animals' acceptance of some of the procedures which will be necessary to keep them working over long periods; namely, the spacing of problems and the requirement of more than one correct response for each piece of food. The animals adapted surprisingly well to these conditions.

Oscar was shipped back to Holloman AFB in accord with the decision made last quarter.

Human Project:

Forty orbits of 2, 3, or 4 hours were completed this quarter with human subjects (laboratory personnel), bringing the total number of orbits completed on the project to fifty. The goal was to develop tasks in which fatigue defined as decrements in performance on complex tasks over long work periods would be clearly apparent. To this end, more modifications were made in the task described in the last quarterly report. Each trial of this problem involves an instruction which lists three colors in a particular order, momentary presentation of colors in three windows of the test panel, and the subject's response of rapidly pushing the windows, as if they were still colored, in the order specified by the instruction.

Three modifications of the Houston task were made to increase the amount of information the subject had to handle on each trial. First, subjects were required to maintain two sets as to the designations of the panel windows. Permanent numbers were assigned each window and the instructions were made a combination of trial-unique color designations and permanent number designations. Performance was better than when all of the instructions were colors. Subjects reported that the numbers were easier than the colors, and that the variety of instructions made the task less monotonous. The instructions were then limited to colors again, and color presentations in the windows were omitted in one-fourth of the trials. On these trials the subject was required to respond on the basis of the array on the previous problem. Three of the six subjects refused to try the problems without a presentation. The other three finished 6 to 11 percent better than they started. The third modification increased the amount of information presented in the three windows from 3 to 6 units by superimposing symbols on the colors and making the instructions a combination of colors and symbols. Figure 5 shows the effect of this modification. Accuracy was about 10 percent less throughout the orbit, but deterioration of performance over time was no more rapid.

The same result was obtained when the display windows were moved farther apart to increase eyestrain (figure 6). There was again a 10 percent drop in overall accuracy, but no change in the slope of the performance line.

Decrements in performance over time of 10 to 56 percent were obtained in 16 of the 27 orbits in which a vigilance requirement was added to the Houston task. Inter-trial intervals were lengthened and made variable (5, 7-1/2, 10, or 15 seconds in random sequence), and the presentation of colors was moved ahead of the instructions so that necessary information was presented before the subject was alerted by sound. Figure 7 shows a typical effect of these changes.

A separate problem assessing only vigilance was added in another window of the panel. A white ball was presented for one second at random intervals throughout the orbit. The subject was required to push a specified window before the light went out. Decrements of 20 percent or more were obtained on this problem in 10 of the last 12 orbits. Figure 8 is a composite of these 12 orbits.

The best decrements were obtained from subjects who claimed to be tired from other work before going into orbit. Figure 9 shows the performance of one subject who was instructed to become fatigued before orbiting. The first dip is a hardly exciting output decrement associated with sleep. There were sleep spindles on the EEG and most of the errors were omissions. This points out that subjects fatigued beforehand may provide less usable data than fresh subjects since we are not interested in sleeping EEGs or total absence of performance. The second decrement is not sleep and is similar to decrements obtained in many other orbits in the gradual slope of the performance line and in the sources of error reported by the subject afterwards. The common error sources were missing the presentations, seeing only part of it, being unable to distinguish elements in it, forgetting it, responding too slowly, and being unable to direct the finger to the windows known to be correct. Comparison of this second decrement with those in figure 10 suggests that deterioration of accuracy is no more rapid in pre-fatigued subjects than in fresh subjects over the performance periods used to date. The gradualness of the deterioration suggest that a greater difference in performance levels will be obtained when orbits are extended beyond the current four hours. Figure 11 shows the only instances of sudden decrements in 50 orbits.

Plans for next quarter include extension of testing to paid naive subjects (probably medical residents), use of a new counting problem in alternation with the Houston problem, doubling the number of different problems on the Houston task, using a buzzer to inform the subject of errors instead of the "X" which currently flashes in one of the panel windows, possibly extending the duration of orbits, and possibly recording reasons for individual errors to see if the types of errors occurring show any systematic change over time. The vigilance problem will be continued without change.

Work was begun this quarter on a paper discussing our efforts to develop tasks producing and demonstrating fatigue in man and primates which will be presented at a NASA Executive Meeting in Washington, D. C. on October 28, 1964.

EEG and Computer Report:

Three of the monkey orbits had the EEG taped and processed on the computer: NA-152, NA-153 and NA-157. The first two have been analyzed and are included in this report. The results of NA-157 will be included next quarter along with the analysis of the human orbits we have begun.

We have tape recorded the EEG from 4 human subjects. These have been digitized, but final analysis is not yet complete.

The recording technique for the humans is similar to that for the monkeys. Three scalp electrodes are used. These are attached to the scalp with surgical tape in a manner suggested by the Houston Center. The electrode paste used for contact was also furnished by Houston. The EEG was recorded throughout the entire experiment. Since in the humans we do not have alternate periods of rest and performance, as with the monkeys, we have altered the zero crossings program to arbitrarily separate the continuous performance into 3 minute periods.

This quarter most of the attention was given to the application of Fieller's theorem (see previous report) to the results of our zero crossings program. For the evaluation of performance and EEG we can consider each orbit as really two orbits, one having a color reversal test as the performance parameter and the other with an interpolated cue as the performance parameter. On this basis, we have a total of 24 experiments on which we have enough samples of information to apply Fieller's theorem.

For 11 of these orbits, there was continuous high output and good performance with no decrement. Likewise the limits of the mean ratio included 1.0 for both the first half of the orbit and the last half. Five of the experiments had continuous poor performance throughout the entire session. In these cases the limits of the mean ratio for the first half of the orbit likewise did not differ from those of the last half of the orbit; however, these limits did not include 1.0. This means that the theta activity is peculiar to the system and not random noise. In 8 experiments there was a decrement in performance during the last half of the orbit. In every case the limits of the mean for the good performance period included 1.0, but during the poor performance periods they shifted so that 1.0 was excluded from the limits. This gives strong plausible evidence that the theta activity is a result of brain function and at least overtly related to performance capability.

We have studied the delta activity and the results are not as consistent. We are in the process of studying the beta activity by this method.

We are fully aware of the limitations of Fieller's theorem, particularly as regards to distribution of the samples, and sensitivity of the changes because of sample size. From an initial look at the human data these limitations may be even more important.

To circumvent these problems we are going to apply other statistical procedures. The first of these that will be used is the Weibull statistic. This is a method in which the cumulative density function is not an integral and, therefore, easily computed; it is $F(x) = 1 - e^{(\frac{x}{\theta})^{\beta}}$. The output of the frequency for each session will be ordered and considered as the failure rate of the system. We are not required to make any assumptions about the population or its distribution, in fact this method provides us with knowledge of the parameters of the distribution, skewness, kurtosis, etc.

In summary then our analysis of the data so far, using Fieller's theorem, has established that there is information in the EEG, at least in the 3 to 7 cps activity that is related to performance. New methods are under development that will increase the amount of information we get, particularly in its relation to performance.

Bio-Electronic Report:

Tic-Tac-Toe Panel.

A system was designed and built to comply with specifications for a tic-tac-toe test as drafted by Dr. Mary Blake. This system is to be used to measure performance of chimpanzees under various stress conditions. The system consists of:

One animal panel. This is a 20 x 20 inches, 1/8 inch aluminum panel with a 4 x 4 array of clear plastic push button windows 1 inch in diameter. There are, thus, 4 rows, 4 columns, and 2 diagonals. The horizontal and vertical distance between adjacent windows is 2-3/4 inches. The windows can be illuminated from the rear of the panel in either one of two colors; we presently use yellow and green though other colors can easily be substituted.

One operator panel. The operator panel has 16 groups of switches with three switches per group; namely, one row switch, one column switch and one "odd" switch. The groups are arranged in a 4 x 4 array like the windows on the animal panel. This panel is also used to house 17 relays (a 4 by 4 array and 1 control relay), a timer, a manual reset switch and various accessory components.

Power supply. Grason-Stadler Model E 783 D which is part of the operant conditioning equipment.

Feeder. Gerbrand Universal Feeder. The operator sets up the desired problem by flipping 4 switches and, thereafter, operating a manual reset switch which will light up the windows in the desired constellation (example: the first three windows from the left in the second row yellow the fourth window in that row green) and make the animal panel active. The animal is now supposed to press the odd colored window (green) in the row, column or diagonal. Pushing momentarily one window will:

a. Render the animal panel inactive for the remainder of the problem cycle.
b. Turn on a yellow light in the window that was pushed.
c. Trigger the feeding mechanism in case the pushed window was the odd one (when the animal responded correctly).
d. Start a timer.

When the timer runs out a control relay will turn off all lights while the panel will remain inactive. The operator can now set up the next problem, and start this problem by operating the reset switch.

Some technical details are as follows: Illumination of the windows is provided for by two bulbs mounted on the bottom of a carton tube 5 inches high and 2-1/2 inches in diameter located behind the corresponding window. This manner of mounting and the use of frosted paper provides an uniform distribution of the light over the window. All switches on the operator panel are Switchcraft Lev-R Type 3004L DPST. The 17 latching relays are Potter and Brumfield Type KB 23 D, 24 volt. The 16 switches used to sense pushing of the windows are Micro-Switch Type BZ-RW 8242.

Transistor Noise Measurements:

The root mean square value of electrical activity of brain as recorded from the scalp by means of small metal discs (5 mm diameter) is usually in the range from 50 to 200 microvolts. If transistors are to be used to amplify this electrical activity, consideration must be given to electrical noise generated in the transistors themselves, as the level of this noise is in many types of transistors comparable to the levels mentioned above. At the low end of the frequency range the noise level in transistors decreases at a rate of 3 db per octave with increasing frequency, it then flattens off at the so-called lower corner frequency, remains flat up to the upper corner frequency and thereafter increases at a rate of 6 db per octave. The noise level is further dependent on the operating point and on the source impedance. A typical value of the lower corner frequency is 1000 c/s though with field effect transistors lower values (300 c/s) can be obtained [1]. The frequency range of interest in the recording of brain activity is from 0.5 to 80 c/s, this range which falls below the lower corner frequency where increased noise levels are to be expected is usually not covered by manufacturer's specifications. It was, therefore, decided to develop a system which would allow us to measure noise levels in the range from 0.5 to 80 c/s. A description of the system together with some of the results obtained with it are reported herewith. The procedure will be illustrated with the following examples:

A silicon epitaxial junction N Channel Field Effect transistor 2N3088 (low noise) manufactured by Crystalonics was used in the circuit of figure 12. The gain and the rms noise voltage of the test circuit were measured with

(1) Field Effect Transistors. Theory and Application Notes No. 3 November 1963. Amelco Semiconductor Division of Teledyne, Inc.

the system as per figure 13, and the results of these measurements are plotted in figure 14. The boxed values gives the noise voltage referred to the transistor gate for the corresponding operating points. The gain of this test circuit at drain to source voltage of 5 V and at a drain current of 1.0 mA was 7.1. It is to be noted that in the execution of this system the 600 Ohm load resistor has been made a part of the test circuit (see figure 13), and that a Low-Pass filter has been incorporated so as to filter out any noise over 80 c/s which is outside the conventional range of brain activity. Initially, considerable trouble was experienced from 60 c/s interference. However, through complete enclosure of the test circuit, including batteries in an aluminum box and by careful shielding of all system interconnections, these troubles have been overcome.

Measurement Procedure

Gain: e_1 is adjusted for 1 volt rms 5 c/s sinussoidal signal and the corresponding e_5 is measured. The gain G follows from:

$$e_1 \times 10^{-4} \times G \times 1000 \times 1/2 = e_5 \qquad \text{or} \qquad G = 20\,(e_5 / e_1)$$

Noise: The oscillator is then turned off and the rms value of e_5 is measured with the true rms voltmeter B&K Model 2603. The noise value follows from:

$$(\text{rms } e_2) \times G \times 1000 \times 1/2 = (\text{rms } e_5) \qquad \text{or } (\text{rms } e_2) = \frac{2 \times (\text{rms } e_5)}{G \times 1000}$$

The noise value thus obtained is the total noise in the frequency range from 0.5 to 80 c/s. Note: A check is made to verify that the low level amplifier noise may be neglected by measuring the noise with the battery supply turned off.

The 2N 3088 transistor has a TO-5 package, is 0.25 inches high and is 0.37 inches in diameter. A much smaller package would be desirable for amplifiers that are to be carried by animals or human subjects. Transistors in a much smaller package than the TO-5 are available. We tested a P channel diffused silicon unipolar field effect transistor 2N3113 made by

Siliconix, Incorporated which has a package 0.1 inch in diameter and 0.040 inch high. The results of noise and measurements on this transistor are shown in figure 15. The gain of this test circuit $V_{GS} = 0$ and at a drain current of - 43 micro-amp was 10. The noise at this operating point was 45 microvolts which means that this transistor cannot be employed in the first stage of an EEG amplifier because of its high noise.

The preamplifiers which are presently being assembled for our 4 channel FM-FM telemetry system (see quarterly report No. 10, figure 24), employs a CK22A transistor in an emitter follower circuit as input stage. The noise level of this stage as measured with the system of figure 13 was found to be 1.4 micro volts rms at the planned operating point. We consider this satisfactory.

Future Plans:

The plans of an unconventional system for the measurement of noise at low frequencies employing operational amplifiers, true rms measuring circuits and definite pre-set integration times are being worked out. Advantages over the present system will be the elimination of meter pointer fluctuations (which reduce the accuracy at low frequencies), and also the extension of the frequency range to values below 0.5 c/s.

We apologize for the delay in providing this report, but the involvement of the chief investigator as General Chairman of the NASA symposium entitled, Analysis of Central Nervous System and Cardiovascular Data Using Computer Methods, particularly contributed to this delay.

In the above report, it will be noted:

1. Human performance and its EEG correlates occupied the <u>major</u> portion of our activities during this quarter.

2. Fieller's theorem has established that there is information in the EEG, at least in the 3 to 7 cps activity, that is related to performance.

3. A novel system has been set up for transistor noise measurements.

Hoping you will find this progress report adequate.

Yours sincerely,

Lorne D. Proctor, M. D.
Chairman-Department of
Neurology and Psychiatry

LDP/ B
Enclosures

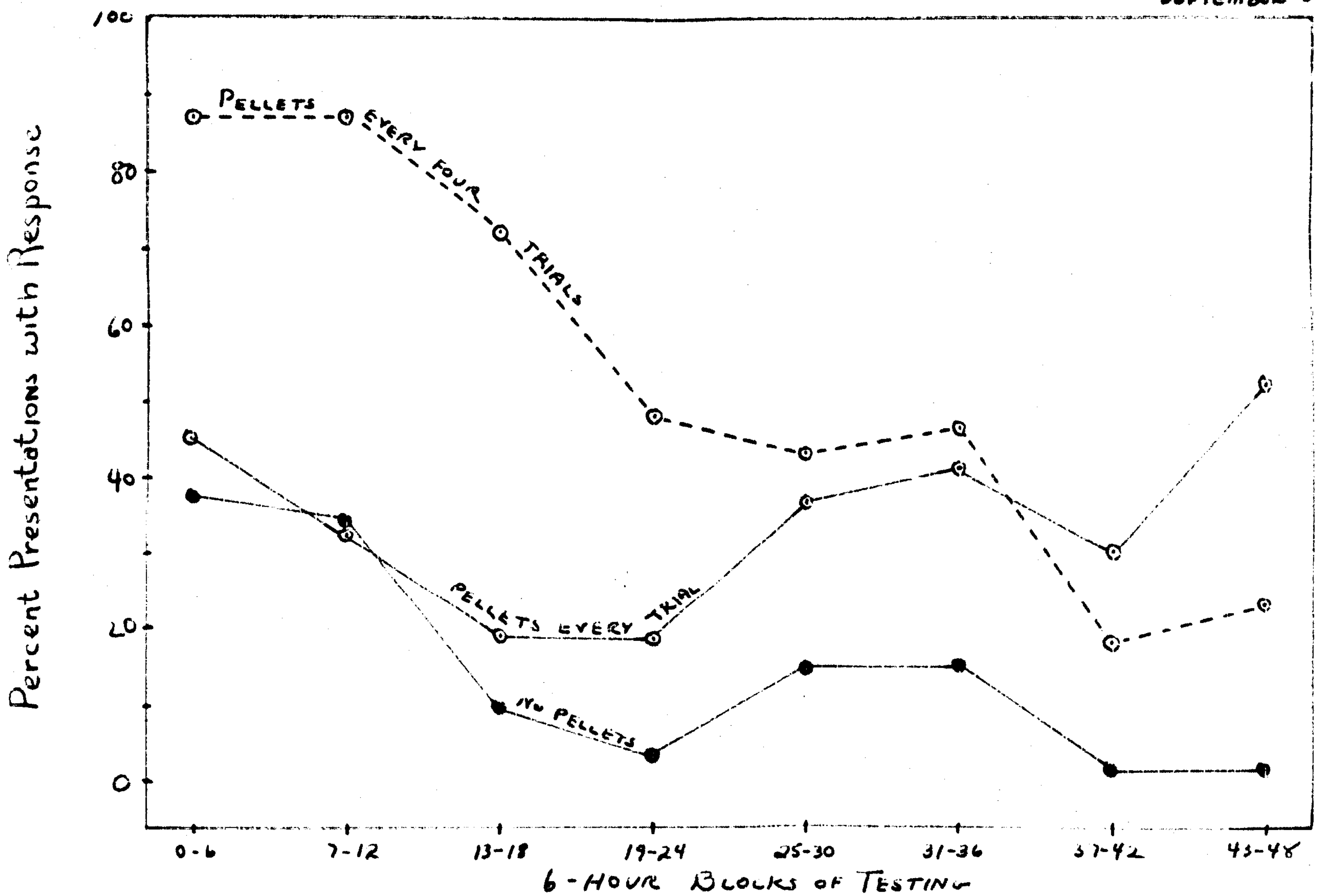


Figure 1. The effect of adding sugar pellet reinforcements to monitoring responses (red light problem) which are already reinforced as a shock-avoidance task. The line representing "Pellets every four trials" is a composite of orbits 156, 157, 158, 159, and 160; that representing "No pellets" is a composite of orbits 152, 153, 154, and 155; that representing "Pellets every trial" is a composite of orbits 142, 143, 144, and 145.

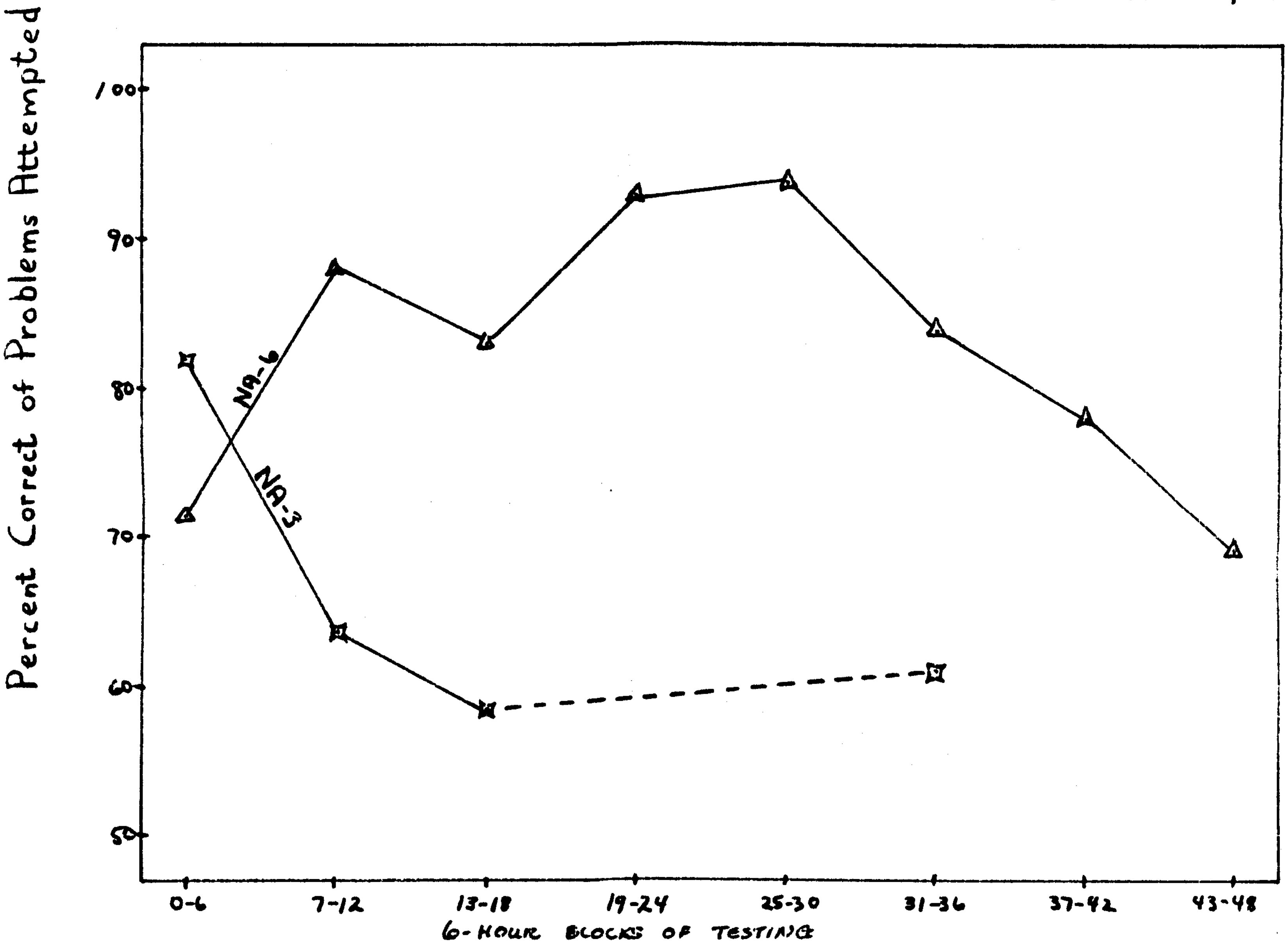


FIGURE 2. ACCURACY OF NA-3 AND NA-6 ON THE REVERSAL PROBLEMS OF ORBITS 156 AND 158 RESPECTIVELY, IN WHICH THERE WAS A VIGILANCE REQUIREMENT. NA-3 RESPONDED VERY LITTLE AFTER THE FIRST 18 HOURS IN ORBIT 156 EXCEPT FOR A SPURT BETWEEN THE 30TH AND 36TH HOURS. ACCURACY IS NOT GRAPHED FOR THE LOW-OUTPUT PERIODS. (OUTPUT LESS THAN 5 PERCENT).

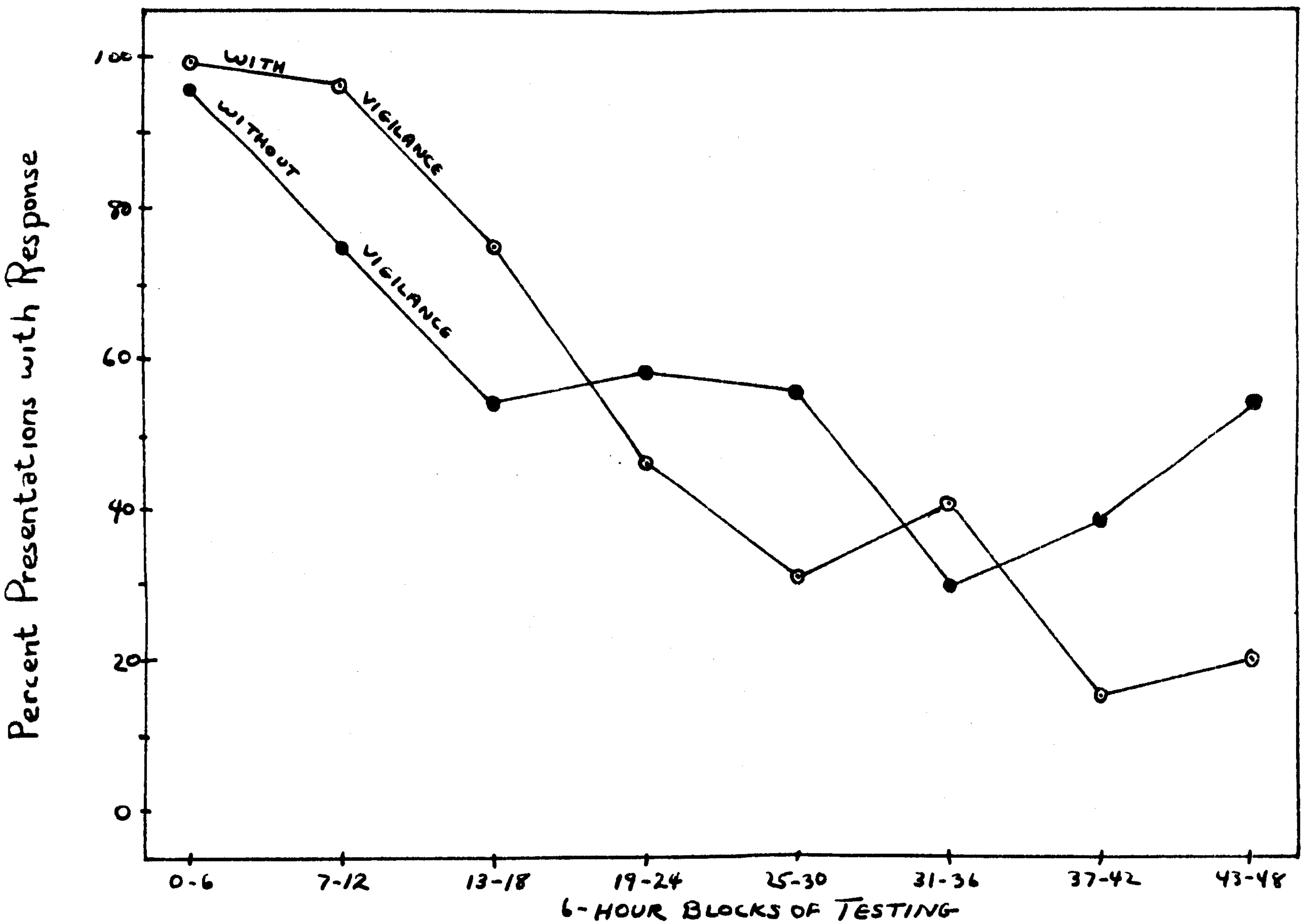


FIGURE 3. OUTPUT OF NA-3 AND NA-6 ON THE REVERSAL PROBLEMS OF ORBITS 156, 158, AND 159 IN WHICH THERE WAS A VIGILANCE REQUIREMENT, AND IN ORBITS 146, 147, 153, AND 154 WHICH WERE RUN BEFORE THE VIGILANCE REQUIREMENT WAS ADDED.

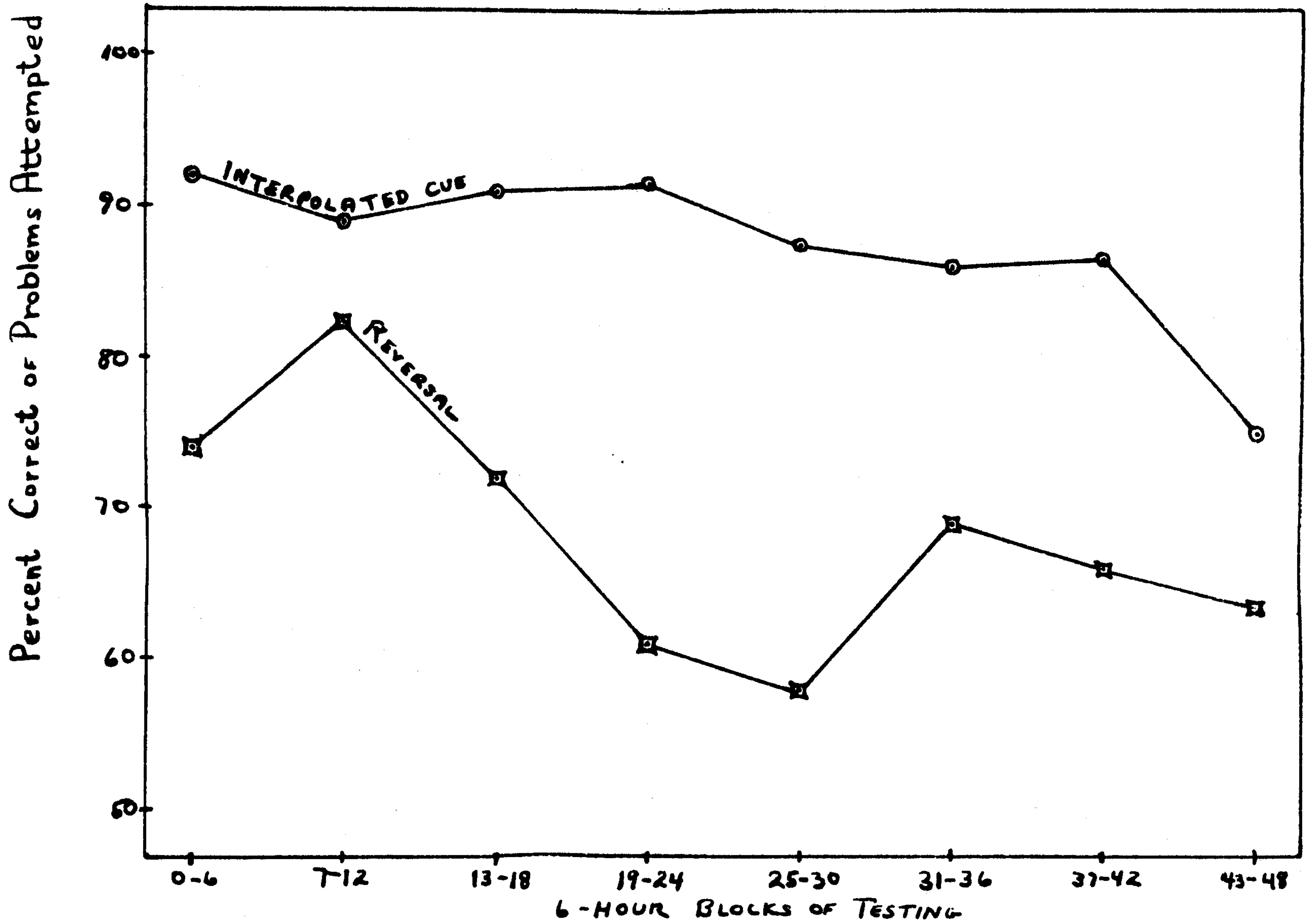


FIGURE 4. ACCURACY OF NA-5 ON THE REVERSAL AND INTERPOLATED CUE PROBLEMS OF ORBIT 157. OUTPUT WAS ABOVE 90 PERCENT IN ALL 6-HOUR BLOCKS OF TESTING.

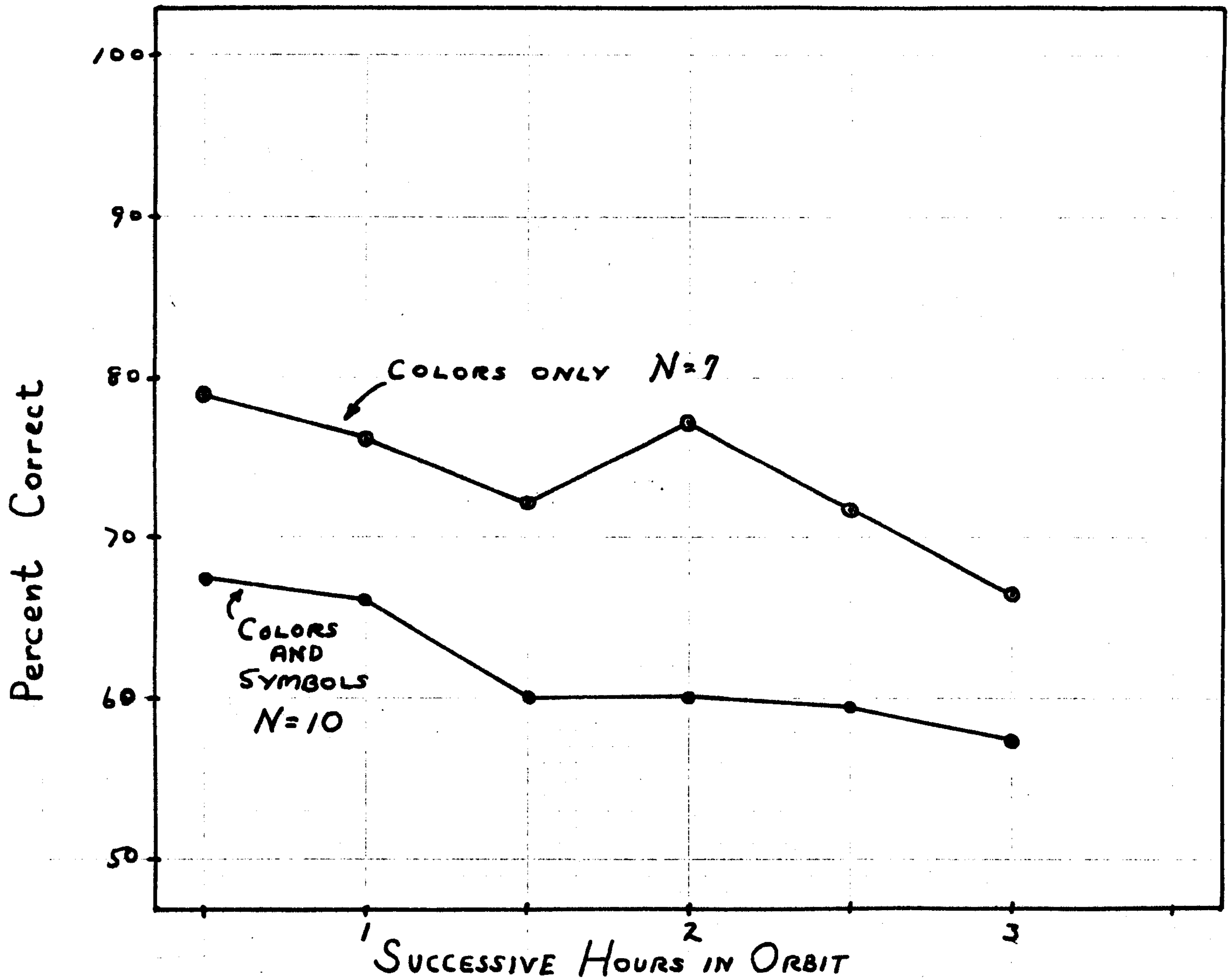


Figure 5 Performance of seven human subjects on the Houston problem (windows together) with a). colors only, and b). colors and symbols, as cues. Some subjects orbited more than once with colors and symbols.

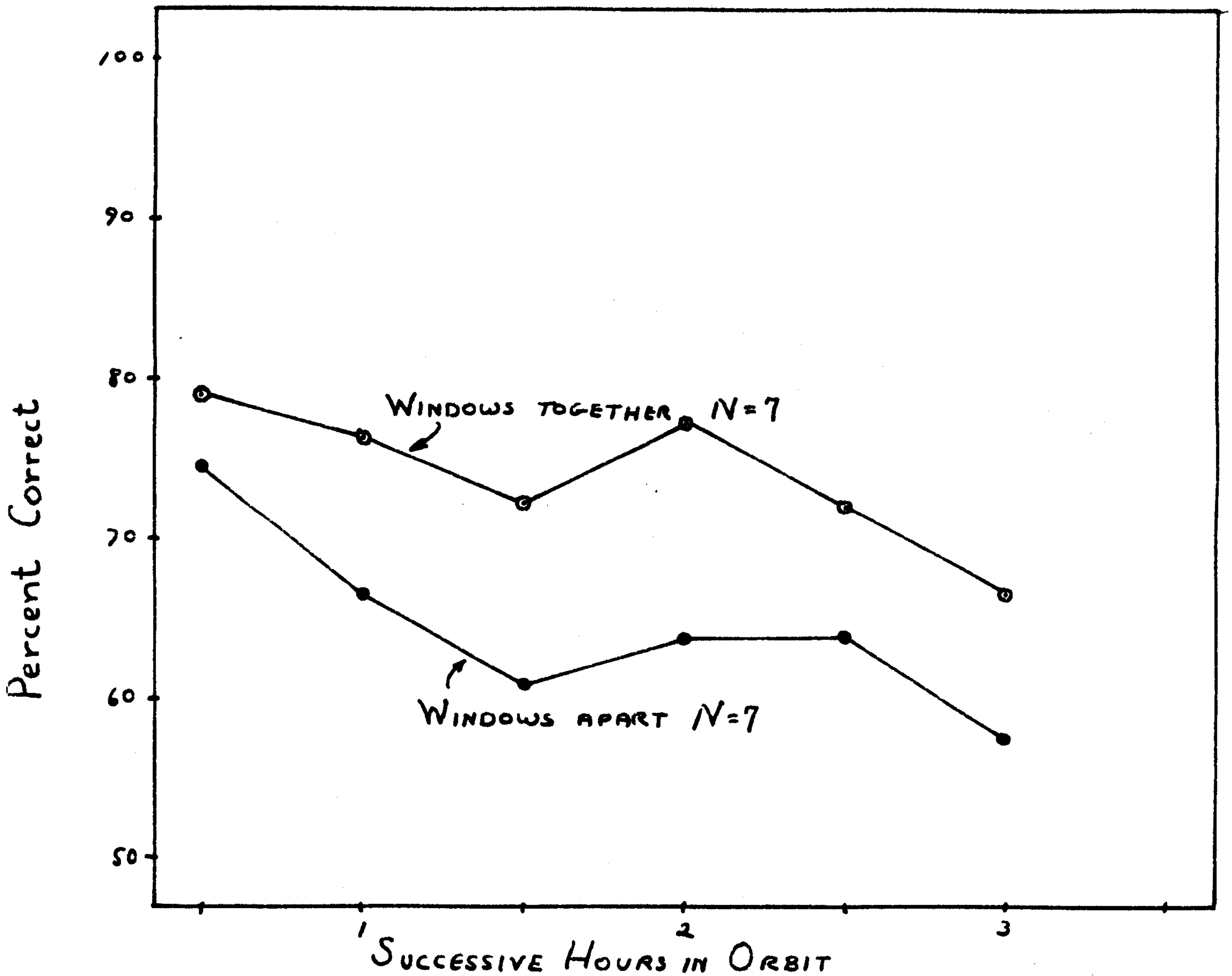


FIGURE 6 PERFORMANCE OF SEVEN HUMAN SUBJECTS ON THE HOUSTEN PROBLEM (COLORS ONLY) WITH a). WINDOWS TOGETHER AND b). WINDOWS APART.

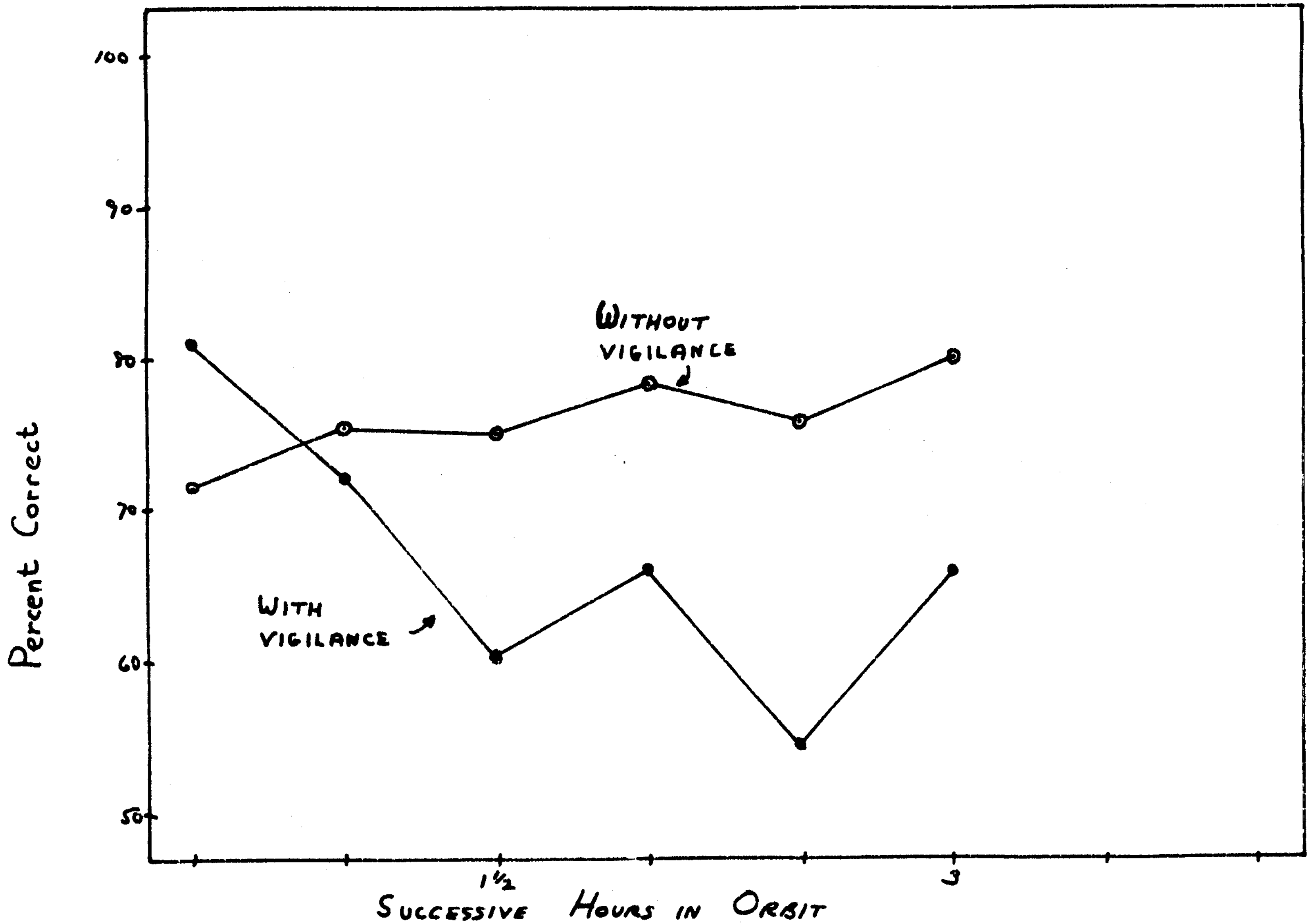


FIGURE 7 PERFORMANCE OF SUBJECT V.H. ON THE HOUSTON PROBLEM IN ORBIT 10 WITHOUT A VIGILANCE REQUIREMENT AND IN ORBIT 21 WITH A VIGILANCE REQUIREMENT.

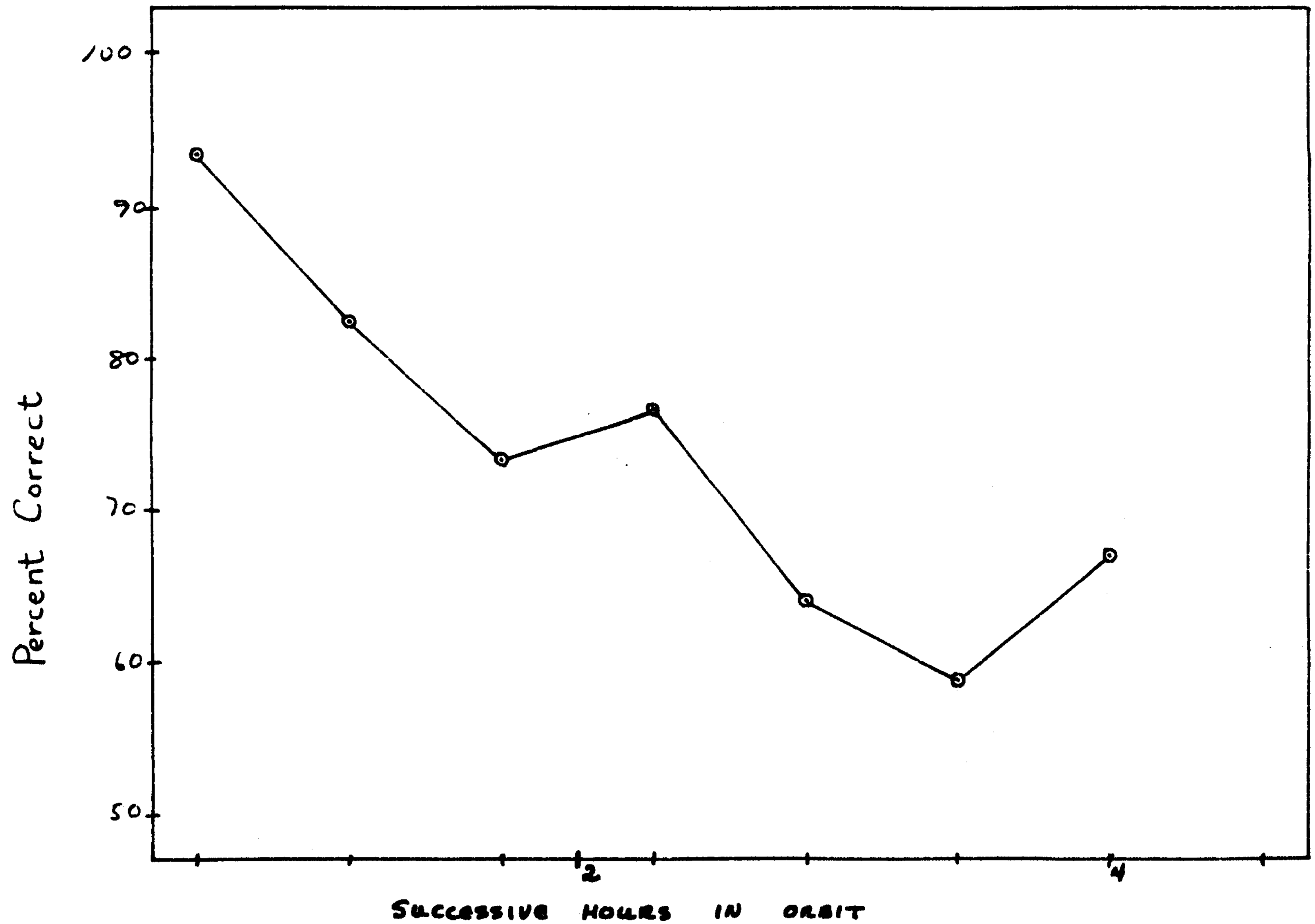


FIGURE 8. COMPOSITE OF PERFORMANCE OF SIX DIFFERENT SUBJECTS IN TWELVE ORBITS ON THE VIGILANCE PROBLEM.

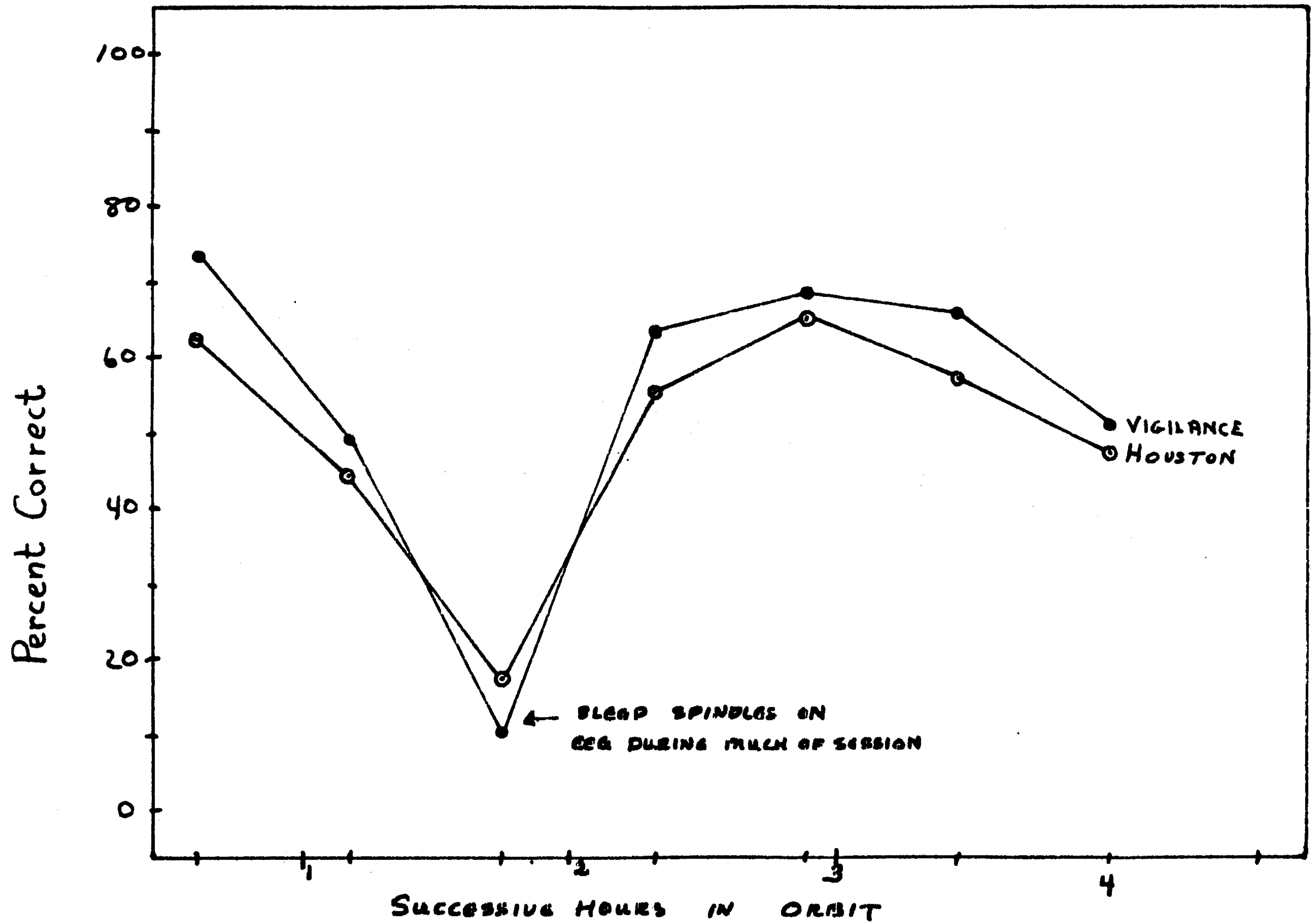


Figure 9. Performance of Subject H.M. on Houston and Vigilance problems in orbit 44 after being instructed to begin orbit fatigued.

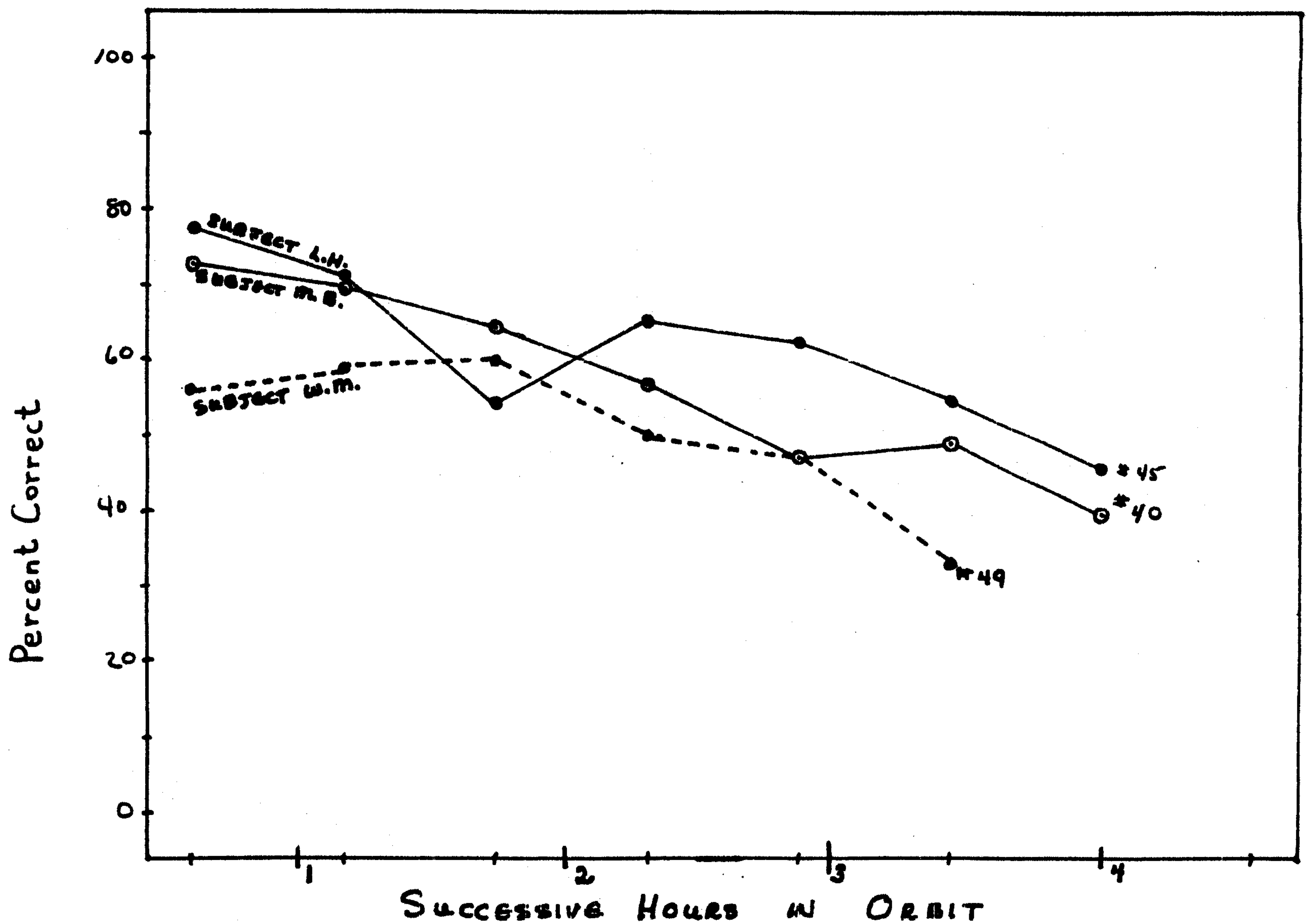


FIGURE 10. PERFORMANCE OF THREE SUBJECTS ON HOUSTON PROBLEM WITH COLORS AND SYMBOLS, AND WINDOWS TOGETHER. NOTE GRADUAL DECREMENT OVER TIME.

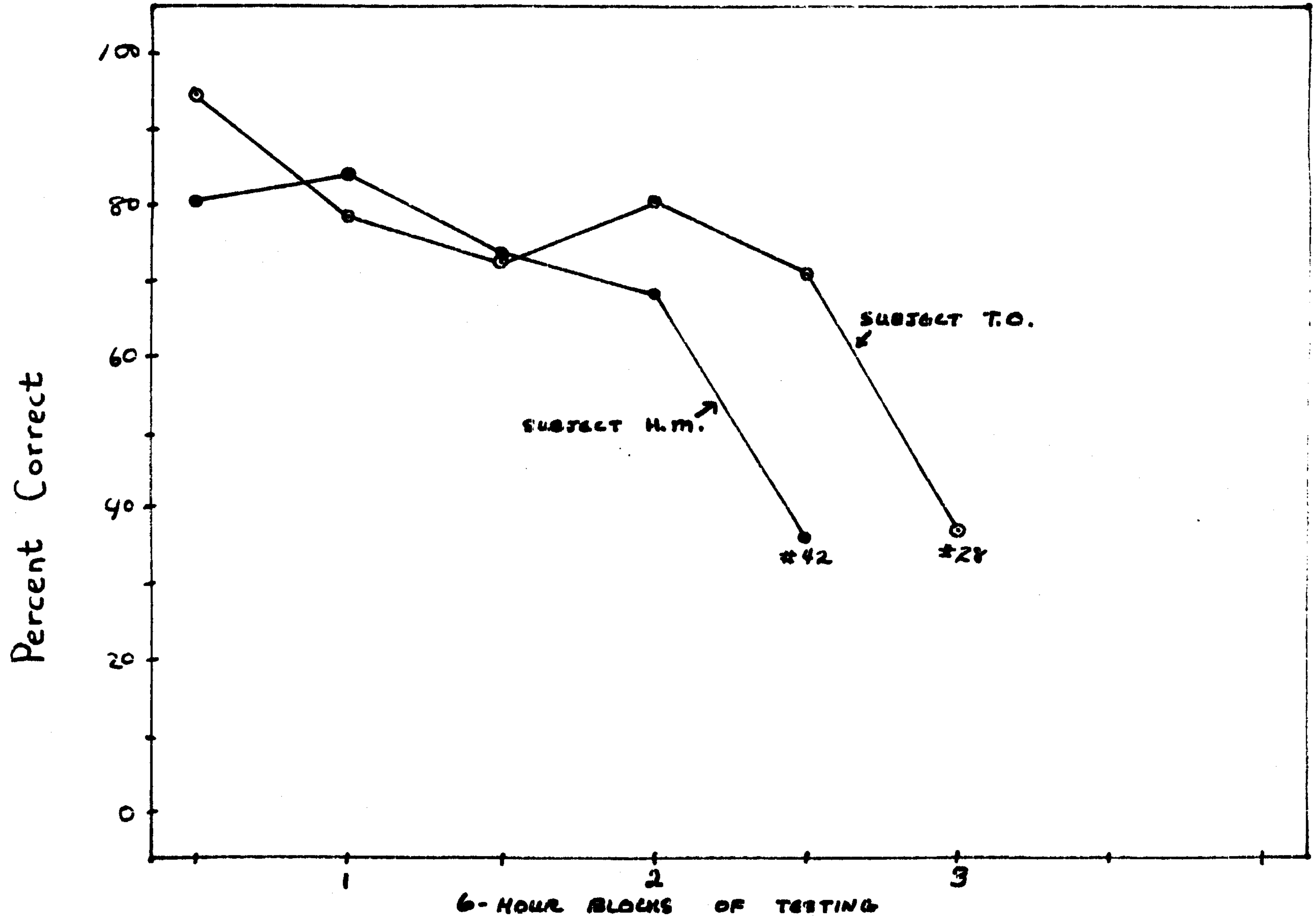


FIGURE 11. SUDDEN DECREMENTS SHOWN BY SUBJECTS H.M. AND T.O. ON THE HOUSTON PROBLEM. (ORBITS 42 AND 28).

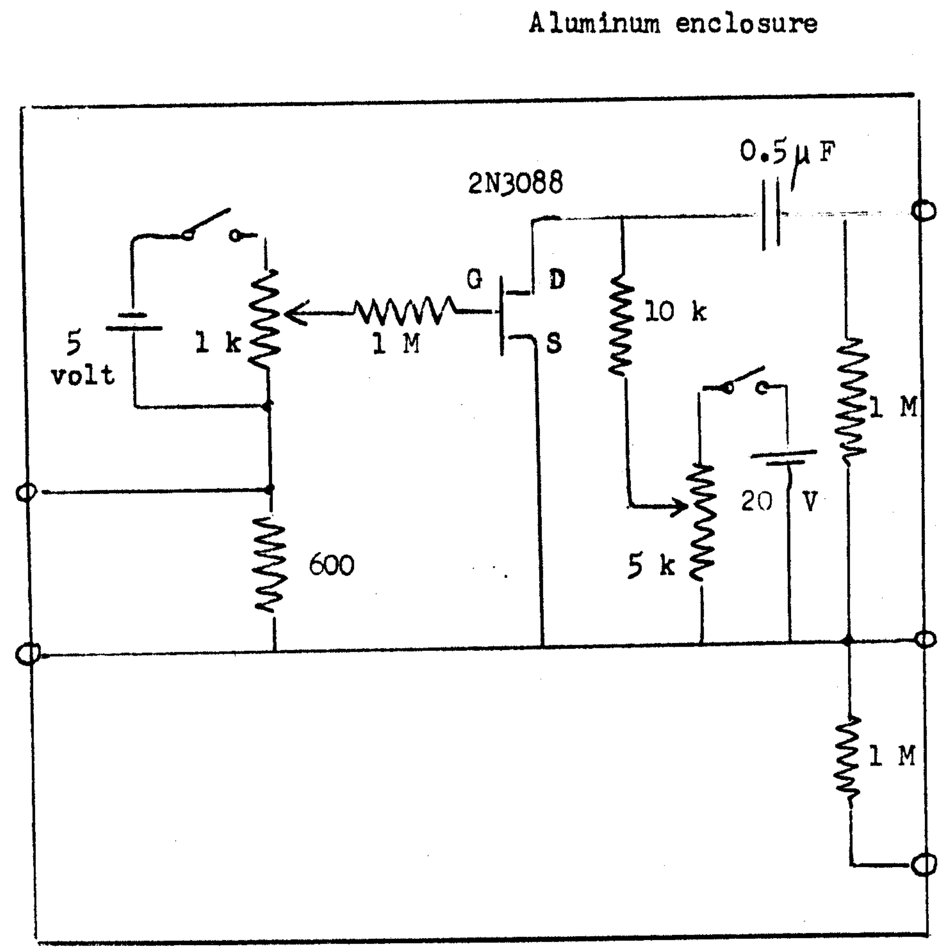
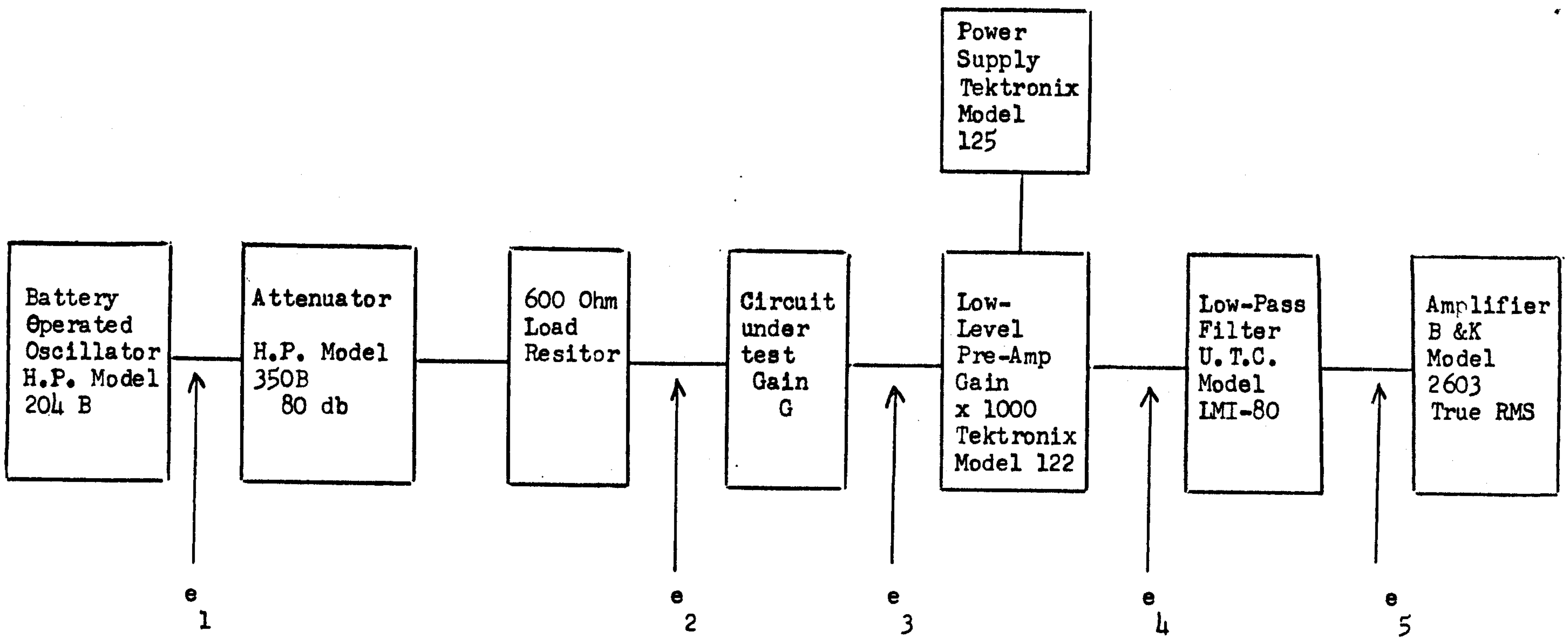


Fig.12. Test circuit in aluminum enclosure



H.P. - Hewlett-Packard
B&K - B&K Instruments Inc.

Fig. 13. System for the measurement of noise levels in transistors.

Fig. 14

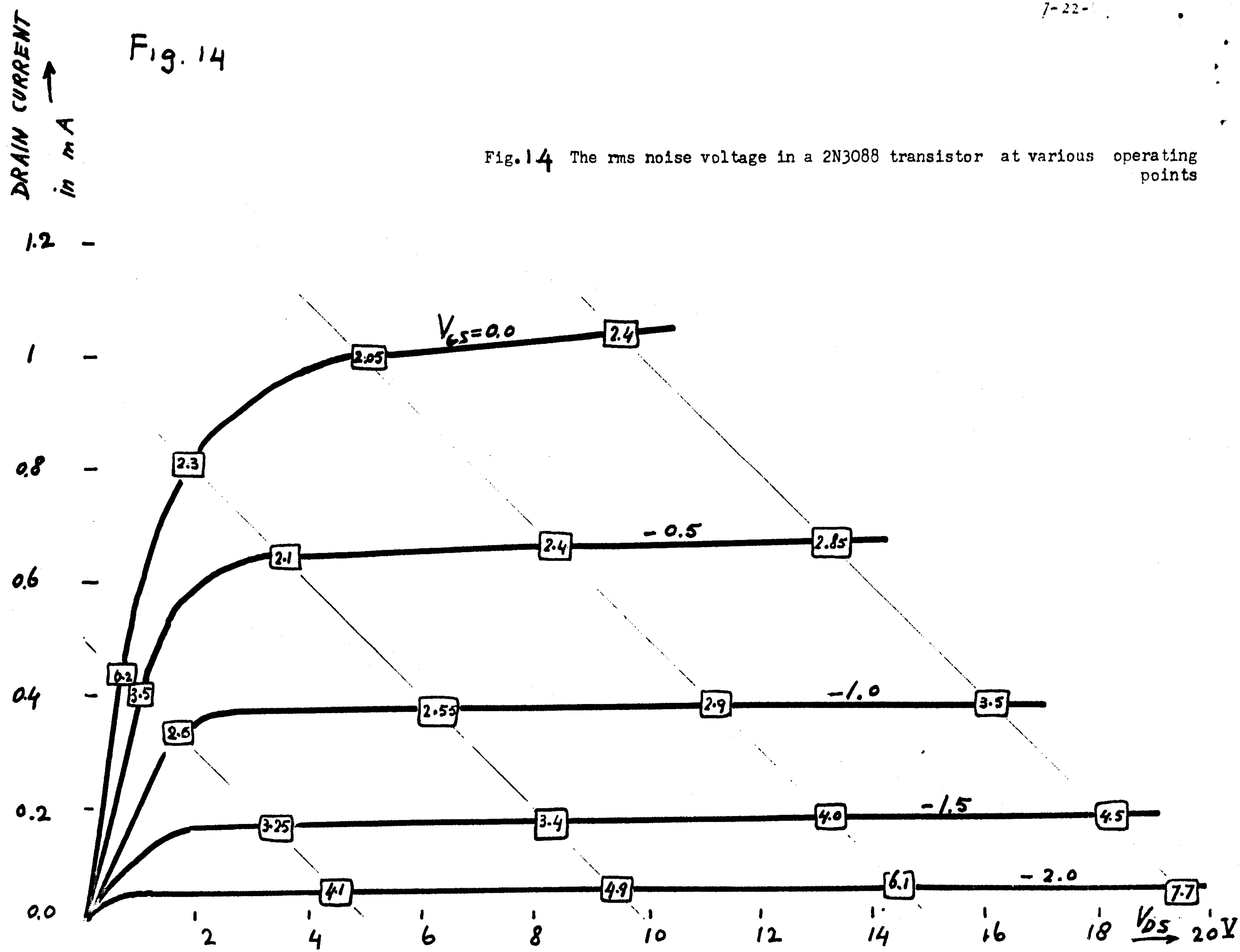


Fig. 14 The rms noise voltage in a 2N3088 transistor at various operating points

NOISE of 2N3113

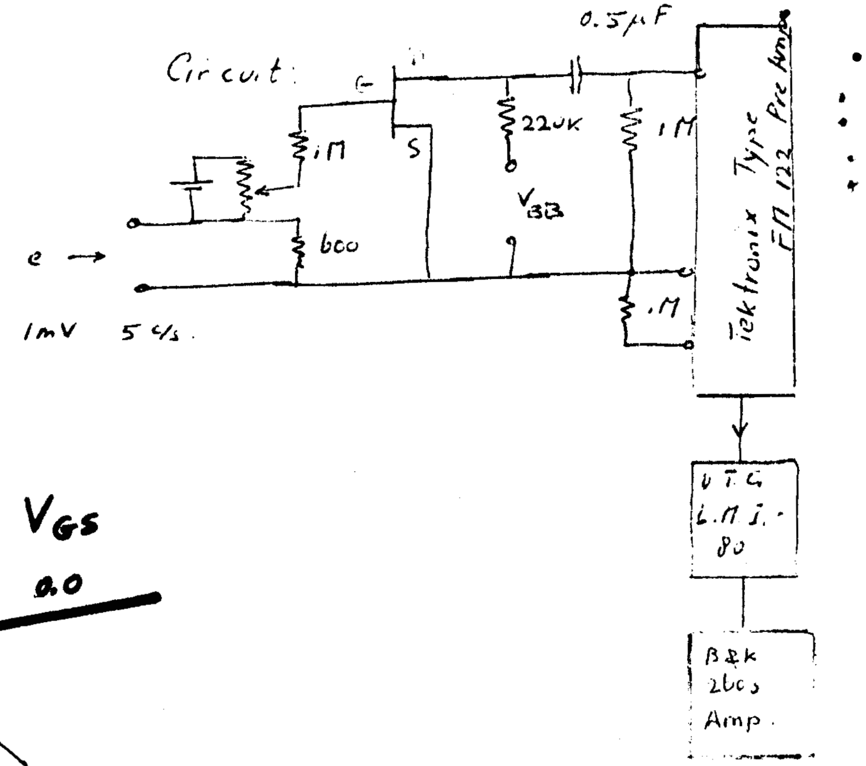


Fig. 15 The rms noise voltage in a 2N3113 transistor at various operating points.